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Assessment of somatic maturation of Venezuelan adolescents

Betty Méndez Pérez[1], María Dolores Marrodán Serrano[2], Consuelo Prado Martínez[3], Julieta Aréchiga Viramontes[4] and María Dolores Cabañas Armesillas[5]

[1]Unidad Bioantropología, Actividad Física y Salud. Universidad Central de Venezuela, Venezuela. [2]Departamento de Zoología y Antropología Física. Facultad de Biología. Universidad Complutense de Madrid, España. [3]Departamento de Biología. Unidad de Antropología. Facultad de Ciencias. Universidad Autónoma de Madrid, España. [4]Instituto de Investigaciones Antropológicas de la Universidad Nacional Autónoma de México, México. [5]Departamento de Anatomía y Embriología. Facultad de Medicina. Universidad Complutense de Madrid, España.

Abstract

Introduction: **beginning of adolescence comprises important physical modifications, which affects growth and changes in body composition, therefore it is important to consider maturation assessment.**

Objective: **to develop a non-invasive method to assess maturity status in Venezuelan adolescents from peak height velocity (PHV) by means of anthropometric variables in a cross-sectional sample.**

Methods: **data comprised 681 Venezuelan adolescents 9 up to 18 years of age. Mirwald equation was applied to derived PHV. Regression analysis was used in order to build a model for Venezuelan sample as well as, ROC curves to assess sensitivity and specificity of anthropometric variables.**

Results: **the predictive equations for both sexes, exhibited a high determination coefficient (< 0.99) and a minimal estimation error (0.06). Mean decimal age at categories of PHV obtained by both equations: criterion and model, were very similar (13.27 *vs.* 13.39) for boys, and (11.62 *vs.* 11.77) for girls. Bland-Altman plot showed a tight concordance between the two equations and all anthropometric indices, exhibited high area under the curve > 0.75, specially sitting height.**

Discussion and conclusion: **in Venezuela, there is little work based on longitudinal studies of the maturation status. Giving the difficult faced in the longitudinal studies recent works have been used cross-sectional methodology in the assessment of the somatic maturation, both in non athletic and athletic populations. This study provides predicting equations for the assessment of the somatic maturation adjusted to Venezuelan population developed from Mirwald equation, which may be used to aid in evaluation of nutritional and general health, as well as, a**

Correspondence: Betty Méndez-Pérez.
Unidad Bioantropologia, Actividad Física y Salud.
Universidad Central de Venezuela.
E-mail: bioantropologiaucv@gmail.com

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EVALUACIÓN DE LA MADURACIÓN SOMÁTICA EN ADOLESCENTES VENEZOLANOS

Resumen

Introducción: **la adolescencia es un período de cambios en la composición corporal, los cuales deben ser considerados en la evaluación del estado de maduración somática.**

Objetivos: **desarrollar un método no invasivo para evaluar el estado de maduración en una muestra transversal de adolescentes venezolanos, a partir del punto de máxima velocidad de crecimiento (PHV), mediante medidas antropométricas.**

Métodos: **la muestra comprende 681 adolescentes venezolanos entre 9 y 18 años. Se aplicó la ecuación de Mirwald para estimar el PHV. De igual manera se efectuó un análisis de regresión para construir el modelo de la muestra venezolana y se aplicaron curvas ROC para evaluar la sensibilidad y especificidad de las variables antropométricas.**

Resultados: **las ecuaciones predictivas para uno y otro sexo mostraron un elevado coeficiente de determinación (< 0,99) y un mínimo error de estimación (0,06). La edad media decimal a la que se alcanza el punto de PHV obtenido por ambas ecuaciones: criterio y modelo, fueron similares para chicos (13,27 *vs.* 13,39) y para chicas (11,62 *vs.* 11,77). El test de Bland-Altman mostró una elevada concordancia entre ambas ecuaciones y todos los indicadores antropométricos mostraron un área bajo la curva > 0,75, en especial la talla sentado.**

Discusion y conclusiones: **dada la dificultad de realizar estudios longitudinales, se han utilizado muestras transversales para estimar la maduración somática en diferentes poblaciones. El presente trabajo proporciona ecuaciones predictivas para este propósito, ajustadas a la población venezolana y desarrolladas a partir de la fórmula de Mirwald. Las mismas pueden ser usadas como ayuda en la evaluación nutricional y de salud en general,**

reduction of risks associated with miss-classification for chronological age.

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Key words: *Maturation. Peak height velocity. Anthropometry. Adolescents. Venezuela.*

así como en la disminución de los riesgos asociados con la clasificación errónea de la edad cronológica.

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Palabras clave: *Maduración. Máxima velocidad de crecimiento. Antropometría. Adolescentes. Venezuela.*

Abbreviation

PHV: Peak Height Velocity.
ROC: Receiver Operating Characteristic Curve.
H: Maximal height.
W: Body weight.
SH: Sitting height.
LLL: Lower limb length.
W/H: Weight to height ratio.
A: Decimal age.
ISAK: International Society for the Advancement of Kinanthropometry.
AUC: Areas under the curve.

Introduction

Beginning of adolescence comprises important physical modifications, which affects growth and changes in body composition[1,2,3,4]. Use of concept of maturity in growth studies involves among others, the principle of somatic or morphological consideration, provided by considerable variability in physical characteristics among individuals of the same chronological age. Scientific evidence shows that is important to consider maturation assessment, the tempo and timing of the progress toward the mature state, in different context and especially around the adolescent growth spurt, for endocrine clinical purposes, growth status and sport classification during the adolescent period[5,6,7,8,9,10]. On the other hand, the nutritional status acting as a modulation factor on the timing of adolescent sexual development is of the utmost importance to be taking into account[11]. Take off growth spurt, the approximate age at which the subject goes through maximum growth during adolescence is named peak height velocity that besides height and weight, influence other body dimensions: growth in leg length, sitting height, biacromial and bicrestal breadth as well as some performance tasks[12,13]. Several studies suggest a combination of environmental and individual factors may be involved in the etiology of maturation, especially genes or environment surrounding factors[14,15]. However, the extent of their influence is somewhat unclear[2,6,16].

Despite the opinions of recognized scientific, there is limited data on the application of maturity concept in the selection of young athletes, although maturation-related classification has been the issue of recent research that has expanded previous views concerning the important role of maturation[17,18,6]. There are several methods of assessing maturation, however some are of high cost, incurs radiation safety issues, unable to use during fieldwork, and in some opportunities considered intrusive by subjects and their parents. On the other hand, maturity data for Venezuelan adolescents are not extensive.

Objective

The purpose of this study was twofold analysis. Firstly, to employ the equations proposed by Mirwald[10] to assess the maturity status of Venezuelan children and youths considering time before or after of peak height velocity (PHV). From that, to develop predicting equations adjusted to Venezuelan population. Secondly, to explore the capacity of anthropometric variables: weight, height, sitting height, lower limb length, and weight/height ratio, to predict the PHV by means of a transversal equation through a non-invasive practical method.

Methods

Subjects

The sample comes from a transversal research about growth, maturation, physical activity and motor performance of children and adolescents. Study protocol was approved by the Ethics Research Committee of the Anthropology School, Universidad Central de Venezuela, which was conducted in accordance with the Helsinski Declaration[19]. All participants gave written informed consent signed by their parents or guardians, after explanation of the purpose and nature of the study. Research material was treated confidentially. Data for this study were obtained from a cross-sectional homogeneous socio-economic data base of Venezuelan children and adolescents from 2009 up to 2012. The subjects attended public schools, in three cities of the country: Caracas, Mérida and San Fernando de Apure. Participants included in the randomized survey were aged 9 up to 18 years, (12.53 ±2.26 yr.) and the final sample encompassed 681 subjects (346 boys and 335 girls).

Anthropometric measurements

Anthropometric dimensions were assessed on each participant of the sample, by three highly trained anthropometrists, according to the procedures of the International Society for the Advancement of Kinanthropometry[20]. Maximal height (H) was measured to the nearest mm with a locally manufactured wall-mounted stadiometer. Body weight (W) was assessed with electronic scale to the nearest 0.1 kg. Sitting height (SH) and lower limb length (LLL) to the nearest mm, were taken as the height from the anthropometric box (where the subject sits) to the vertex and from height minus sitting height respectively. Weight to height ratio (W/H) was calculated using the weight and height measurements. Finally, decimal age (A) was considered. Data quality control was implemented for all team members. Technical errors of measurements were well within the range of errors allowed by ISAK: body mass (0.50 g), height (0.12 cm), and lengths (0.29). Data for continuous variables were expressed as means ± SD for normally distributed data.

Statistical analysis

Statistical analysis and graphical representations of the collected data were performed using the statistical package for the Social Science (SPSS 21.0) software for window. (SPSS 21.0 Inc., Chicago, IL). Statistically significant was considered as $P<0.05$.

Descriptive statistics calculations included means and standard deviation for all the anthropometric variables considered by sex and age. The Kolmogorov-Smirnov normality test, was used for the analysis of equality of continuous distribution. Mirwald equation[10] was applied to derived PHV in a cross-sectional sample. This formula express years from PHV and has been considered as a measurement of maturity status. According with this proposal, it is possible to categorized eight levels based on years of distance from that moment (-4, -3, -2, -1, 0, 1, 2, 3).

In order to build a model for Venezuelan sample, correlation coefficients between PHV obtained by Mirwald[10] expression and the anthropometric dimensions of the sample was calculated. In addition a regression analysis step by step was applied, taking Mirwald's PHV as the dependable variable and the anthropometric variables as the independent ones, this is to say, higher R^2 and lowest estimation error.

To validate the developed equations, 60% of the sample was taken in a probabilistic way. In this subsample PHV by Mirwald (criterion) and PHV by equation obtained in the present study (model), were applied. Thereafter, to analyze the results derived from both equations intraclass correlation coefficient[21] was applied, and the models reliability was expressed by the Bland-Altman graph representation[22]. Next, relationship between mean decimal age of different maturation categories, derived from the criterion and model equation was established by a T-student test for paired samples. Finally, a Receiver Operating Characteristic Curve (ROC analysis)[23], was used to determine the efficacy of a reference test based on anthropometrics variables, considering the status of maturation as the criterion variable (PHV<0; PHV≥0). Areas under the curve (AUC), sensitivity (true-positive rate) and specificity (true-negative rate) were calculated for a range of cutoffs for the reference test.

Results

Means and standard deviation for various body dimensions (not shown in the text) were estimated by age and sex. Age (A), weight (W), height (H), sitting height (SH), lower limb length (LLL), weight/height ratio (W/H). As was expected all variables increase with age.

Table I summarize information from the correlations between decimal age, anthropometric variables and PHV criterion. All of them are significant correlated for boys and girls ($p\leq 0.05$) ranging from 0.659- to -0.979 in boys and 0.526 to 0.979 in girls respectively.

Table I
Correlation coefficients between decimal age, anthropometric variables and Peak height velocity obtained from Mirwald equation

		Boys (N=346)						
		Decimal age (yr)	*Height (cm)*	*Weight (kg)*	*Sitting height (cm)*	*Lower limb length (cm)*	*Weigth/ height*	*PHV criterion*
Girls (N=335)	Decimal age (yr)	1	0.846**	0.753**	0.824**	0.777**	0.659**	0.966**
	Height (cm)	0.693**	1	0.885**	0.940**	0.950**	0.781**	0.926**
	Weight (kg)	0.711**	0.794**	1	0.882**	0.794**	0.979**	0.849**
	Sitting height (cm)	0.728**	0.764**	0.764**	1	0.786**	0.802**	0.941**
	Lower limb length (cm)	0.528**	0.648**	0.891**	0.551**	1	0.680**	0.815**
	Weigth/height	0.626**	0.979**	0.551**	0.671**	0.526**	1	0.755**
	PHV criterium	0.966**	0.773**	0.671**	0.866**	0.650**	0.682**	1

The predictive equations for males developed by this study using a lineal regression where PHV derived from Mirwald[10] acts as dependent variable data and A, W, SH, LLL, and the ratio W/H as predictive variables, was showed in table II. According with the p value (<0.001), the chosen predicting model, for males and females, exhibited a high determination coefficient (<0.99) and a minimal estimation error (0.06).

Table III shows mean decimal age at categories of PHV obtained by both equations: criterion and model. The “0” value represents the age at which the subject goes through maximum growth during adolescence. The mean decimal age at this category were very similar (13.27 vs 13.39) for boys, and (11.62 vs 11.77) for girls accordingly. No statistical differences were found between mean decimal age for all categories.

Table II
Predicting equation of Peak height velocity (yr) derived from the sample

Dependent variable	*Regression equation*	*N*	*Sex*	R^2	*Estimation error*	*P*
PHV (yr)	PHV=-12.909+0.0449*A+0.081*W+0.087*SH–0.023*LLL–12.157*(W/H)	346	B	0.998	0.0632	<0.001
PHV (yr)	PHV=-15.141+0.503*A+0.004]W+0.080*HT–0.049*LLL–6.085*(W/H)	335	G	0.998	0.06628	<0.001

PHV = Peak Height Velocity (years); A = decimal age; W = weight; SH = sitting height; LLL = lower limb length; (W/H) = (weight/height); B = boys; G = girls.

Table III
Decimal age by maturation from criterion and model equation of PHV

			Boys		
Categories	*N*	*PHV criterion*		*PHV model*	
		Mean	*SD*	*Mean*	*SD*
-4	35	9.02	0.36	9.02	0.14
-3	59	9.69	0.57	9.72	0.55
-2	54	10.92	0.63	10.96	0.62
-1	30	12.03	0.61	12.03	0.61
0	16	13.39	0.69	13.27	0.64
1	10	14.49	0.62	14.48	0.66
2	8	15.96	0.80	16.07	0.72
3	4	16.94	0.67	17.12	0.63
			Girls		
Categories	*N*	*PHV criterion*		*PHV model*	
		Mean	*SD*	*Mean*	*SD*
-2	17	9.48	0.34	9.48	3.54
-1	44	10.55	0.72	10.45	0.47
0	59	11.77	0.58	11.62	0.70
1	32	13.07	0.92	12.83	0.82
2	22	15.13	1.01	14.93	1.01
3	10	16.53	0.91	16.41	0.82
4	3	17.94	0.75	17.97	0.70

The intraclass correlation coefficient between criterion and model PHV was 0.99 for boys and girls. This result evidence a very high concordance according to Prieto proposal[21].

As show in figure 1, a Bland-Altman plot of the data for boys and girls exhibited a tight distribution of the difference between the two models. A great majority of the plotted points are located between two standard deviations (± 2 SD), evidenced by the almost perfect adjustment of points showed by the female group.

The ROC curves for anthropometric variables in boys and girls are shown in figure 2. AUCs showed for both, boys and girls, SH as the variable with more capacity to predict the PHV, (boys: 0.971; girls: 0.897) although, all anthropometric indices exhibited high area under the curve > 0.75 (Table IV). In generally, the AUCs in boys were slightly higher than those in girls.

Discussion

It has been emphasized that maturity assessment has received increasing attention for clinical purposes, sport classification during the adolescent period and the relationship between stages of somatic maturation and body composition[24]. Less has been empathized about the role of childhood overweight and nutrition on the earlier timing of puberty. On this sense Cheng[25], have made a detailed revision on the role that nutrients (fat, fiber, protein intake, isoflavones) play on development and the take-off of PHV. The contribution of Boyne[26] on the afro-Caribbean children, deserves special attention, which related BMI with advanced pubertal development. In fact, assessing the developmental tempo in adolescents is an important issue in health screening[5,12], since the range of variability even within the same chronological age is large and shows a striking increase ostensibly during the adolescent growth spurt[27,28,6].

Likely, over the past few decades we are aware of the participation of younger in competitive sports where chronological age is the classification criterion in spite of the differences among body dimensions and motor task. Consequently, the likelihood of erroneous classification is possible when data based on chronological age is used[29].

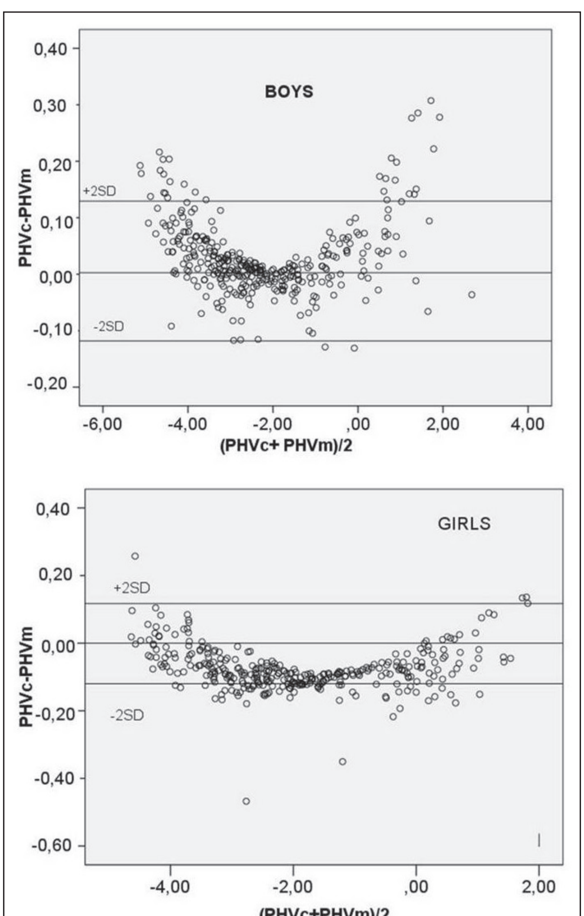

Fig. 1.—Bland-Altman plot of the difference between the two models: criterion and model for boys and gils.

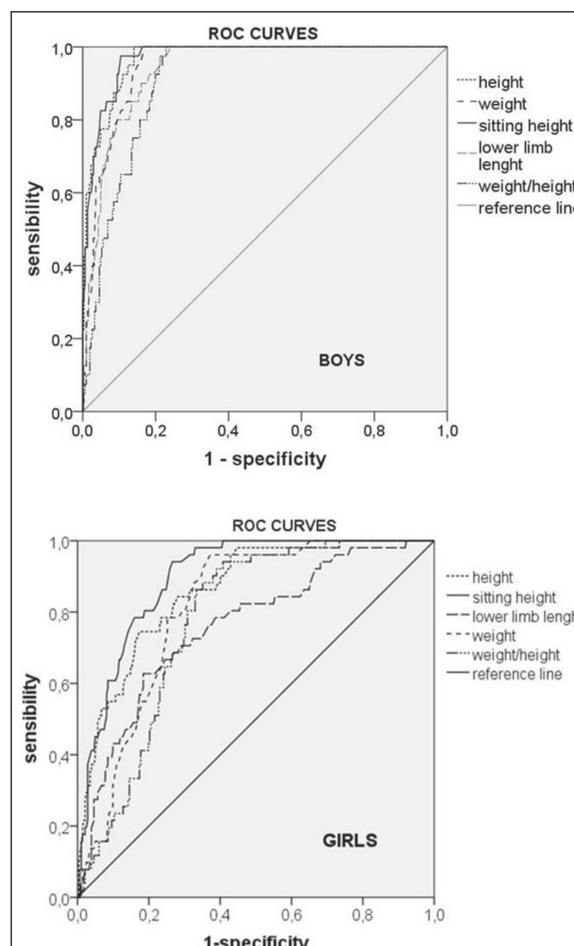

Fig. 2.—Receiver Operating Characteristic (ROC) curves for anthropometric variables o predict PHV in Venezuelan boys and gils.

Table IV
Area under the receiving operating characteristics (ROC) curves for the studied anthropometric variables

Measurement	*Boys*		*Girls*	
	AUC	*CI (95%)*	*AUC*	*CI (95%)*
W	0.948±0.012	0.926-0.971	0.812±0.025	0.762-0.862
H	0.969±0.009	0.952-0.986	0.861±0.025	0.812-0.910
SH	0.971±0.008	0.955-0.987	0.897±0.018	0.861-0.933
LLL	0.938±0.014	0.912-0.965	0.759±0.037	0.688-0.831
W/H	0.967±0.016	0.877-0.941	0.777±0.027	0.723-0.831

AUC: Area under the curve, CI: confidence interval, W: weight, H: height, SH: sitting height, LLL: lower length limb, W/H: weight/height.

The goal of this research was to develop a simple, inexpensive and non-invasive method to assess maturity status in Venezuelan adolescents from peak height velocity (a measure of maturity offset), by means of anthropometric variables in a cross-sectional sample. In Venezuela, there is little work based on longitudinal studies of the maturation and to the best of our knowledge, the only study based on longitudinal data was the reported years ago[30]. Moreover, differences of Latin American population in body composition and maturation have been reported that implies the use of specific equation for these features[31,32].

The equations found here were sustained on the variables that presented highest partial correlation coefficient with decimal age and the position adopted for them under the ROC's curve. In our study, very high correlations were found among decimal age and the anthropometric variables used for the analysis, specially SH that showed for both sexes the highest values. This means that they could be considered in a cross-sectional sample as good predictors for the PHV.

In our sample, PHV was achieved, 2.65 years earlier in females than in males. These findings slightly differ from the study of Gómez Campos[33], who reported a PHV at 14.84 and 11.99 years for Brazilian boys and girls respectively, with a difference of 2.85 years, which favors the female group.

Giving the difficult faced in the longitudinal studies (time consuming, surveillance of subjects along the research, secular changes, among other), recent studies have been used cross-sectional methodology in the assessment of the somatic maturation both in non athletic and athletic populations[17,18,33].

It is worth mentioning that the results of this study have possible limitations related to representativeness of the sample and deserved more detailed study and that, further verification, on different samples including larger number of subject is thus recommended, in order to provide additional information related to this topic. On the other hand as stated by Cheng[25], the role of nutrition, which is an important lifestyle factor, on the onset of puberty, has to be considered in futures studies.

In spite of that, the equations proposed in the present study were sustained on the anthropometric variables that presented the highest partial correlation coefficient with decimal age of the subjects, and the position for them adopted under the ROC curves.

In conclusion, this study provides predicting equations for the assessment of the somatic maturation adjusted to Venezuelan population developed from Mirwald equation[10]. The anthropometric measurements: height, weight, lower limb length and specially sitting height, may provide insights for the measure of biological maturity during the growth period. The obtained equations may be used as potential tools for the prediction of somatic maturation, to aid in evaluation of health and general well-being of children, as well as a reduction of risks associated with miss-classification for chronological age.

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